SAFETY AT HIGHWAY-RAIL CROSSINGS

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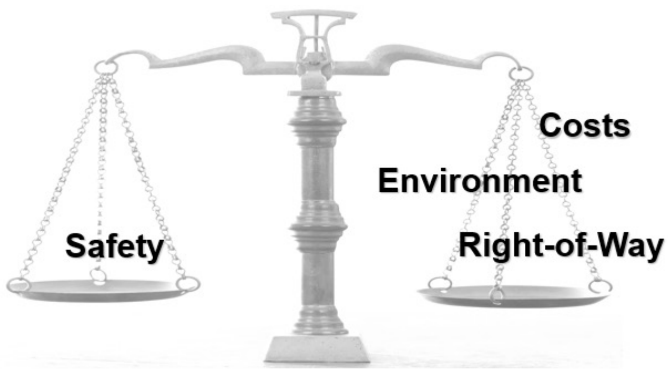
Highway Safety

- Highways designed and constructed to prevailing standards do not guarantee total safety
- Crashes happen due to a combination of factors that are frequently difficult to fully ascertain or understand
- Design standards are based on research and adopted by standard-setting organizations (e.g., AASHTO or ACI in the US)

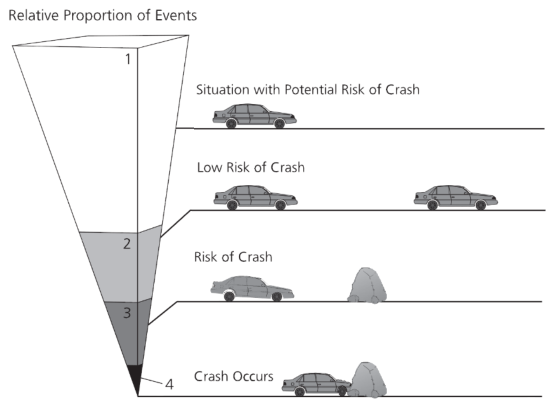


Highway Safety

- Design standards provide nominal safety – this safety level is acceptable and based on trade offs and long-term experience; however, it is not exactly known
- Substantive or quantitative safety is the actual safety performance for a facility based on crash frequency and severity; it is determined over a relatively long time period
- Safety will vary for different types of highway facilities – safety assessment is based on the safety record of similar facilities over a long time period
- Highway Safety Manual (HSM) provides guidance on the assessment of different types of facilities (highway-rail crossings are not yet included)

Measures of Safety

- Several measures may be used:
  - Crash frequency (e.g., number of crashes/year)
  - Crash rate (e.g., number of crashes/million vehicle miles)
  - Crash injury severity (e.g., KABCO, AIS)
  - Equivalent crashes (e.g., equivalent property damage only accidents)
  - Crash costs ($)
- Crashes are relatively uncommon
- We sometimes rely on surrogate measures



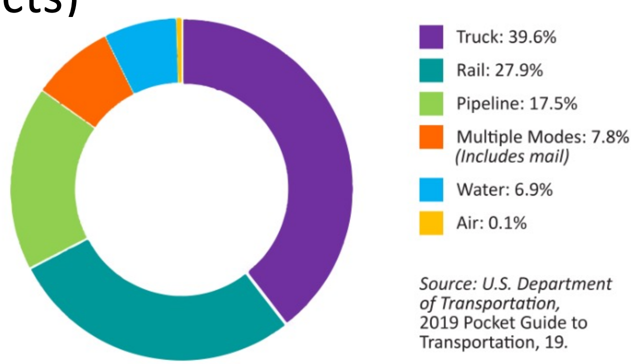
Highway-Rail Crossings

- At-grade highway-rail crossings
  - Represent locations where highways/roads and rail tracks cross at the same level
  - Critical junction in the transportation network
- Most of the US rail system is privately owned and engaged in freight transport
- About 212,000 rail crossings & 140,000 miles of track
- Heavy freight such as coal, lumber, ore, ag products frequently transported over long distances
- Hazardous materials are frequently transported

Source: TR News, 2013

Freight Overview

- 7 Class I railroads, 22 regional railroads, 584 local/short line railroads (all privately owned)
- Provides 167,000 jobs nationwide; nearly $80 billion industry
- Railroads own and maintain tracks, spending $25 billion annually on maintenance and additional capacity
- Railroads move 28% of US freight by ton-miles (52% bulk commodities and 48% consumer + misc. products)



Freight Overview

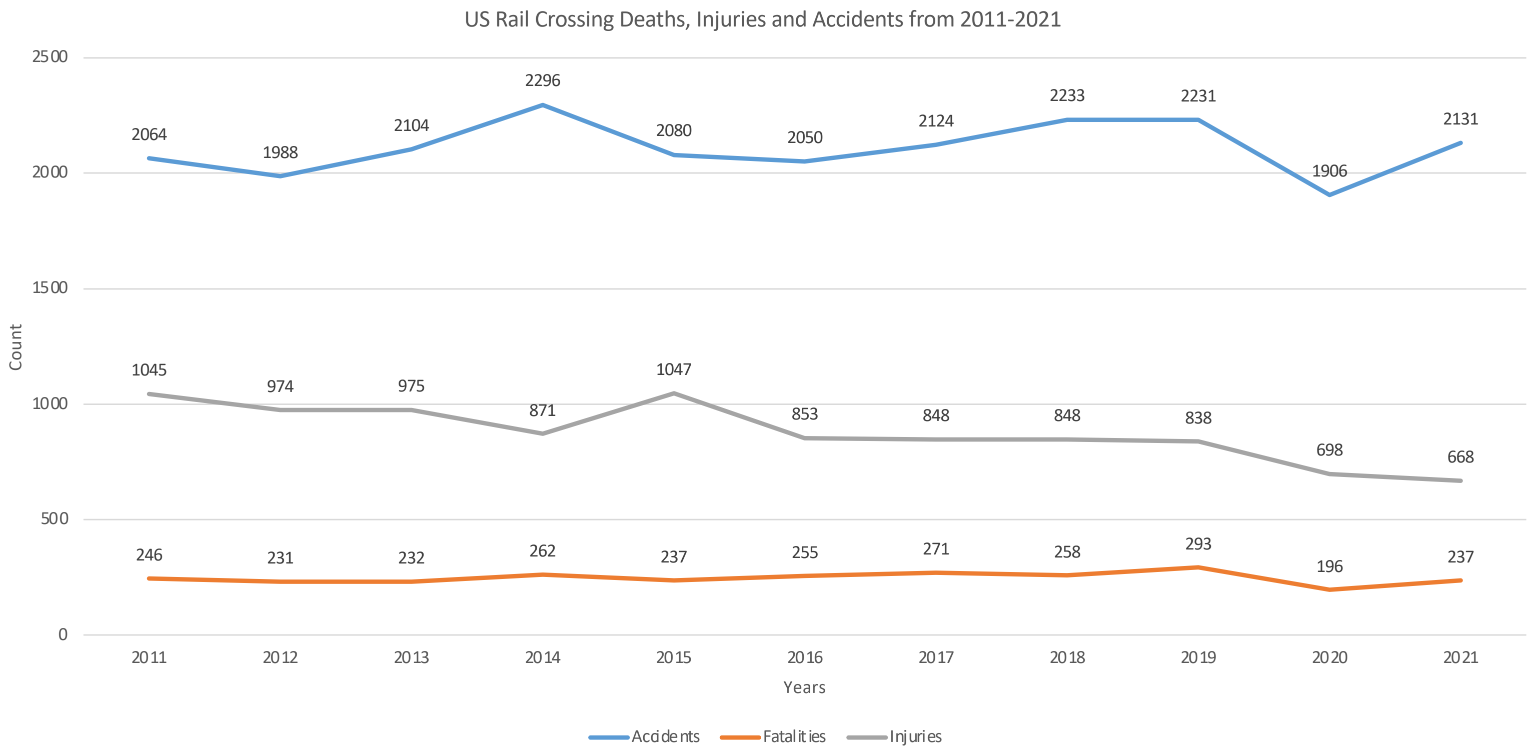
- Railroads utilize a variety of cars depending on the goods being transported
- Freight trains average 73 cars but trains in the 150-200 cars are becoming common
- Fuel efficiency is higher with railroads – one ton of freight can be moved 470 miles on a single gallon of diesel fuel
- Trains are four times more efficient than trucks

Safety at Highway-Rail Crossings - Why Important?

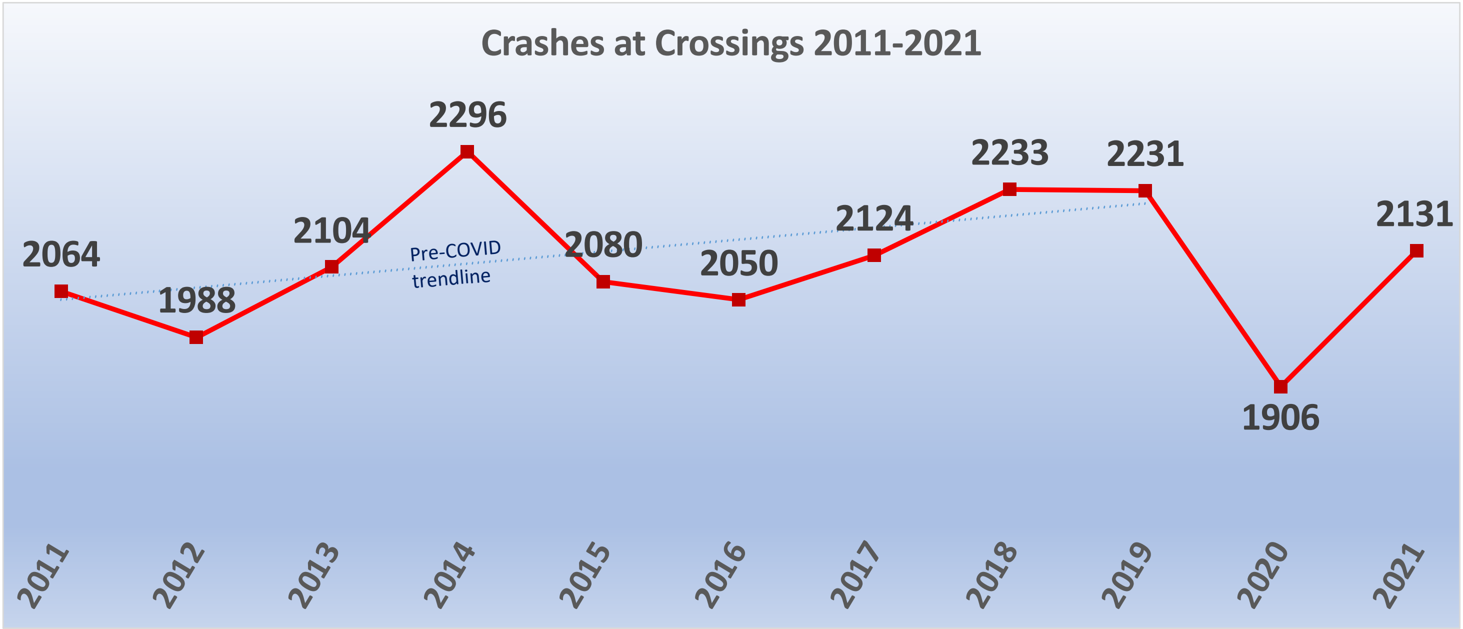
- Crashes are typically more severe and crash costs high
- Crashes can potentially affect both rail and highway networks thus disrupting supply chains reliant on those two networks
- Annual combined grade crossing crash costs are estimated around $650 million in the US

US Rail Crossing Safety Trends

There are about 212,000 crossings (both public and private) in the US (Source: FRA)



Crashes at crossings increasing over the previous 10 years (when not considering the impacts of COVID on accidents)



Fatalities at crossings increasing over the previous 10 years (when not considering the impacts of COVID on fatalities)

U.S. Department
of Transportation
Federal Railroad
Administration

Railroad Crossing Safety and Trespass Prevention

December 2015

Combined, railroad crossing and trespasser deaths account for approximately 96 percent of all rail-related deaths.

About every 3 hours, a person or vehicle is hit by a train

Crossings in the U.S.

64% 36%

Roughly two-thirds of public crossings are **active** (include gates, bells, and/or flashing lights) while the other one-third are **passive** (include signs and markings, but do not include active warning devices). Always expect a train on any track at anytime.

The U.S. Railroad System

750
Railroads

140,000
Miles of track

212,000
Railroad crossings

67%
More than two-thirds of railroad crossing accidents occur in clear weather conditions

Trains cannot stop quickly! A train traveling at 55 MPH takes a mile or more to stop!

For more information on rail safety, visit our Statistics page under the Railroad Crossing Safety tab.

Safety Trends

Although rail incidents have been in decline…

-24 %
In the past 10 years fatalities at U.S. crossings have declined substantially.

-33 %
Similarly, over the same 10 year period, trespassing fatalities have also declined.

2014 saw Railroad Crossing fatalities increase…

In 2014 there were approximately 270 fatalities at railroad crossings, an increase of 40 from the previous year.

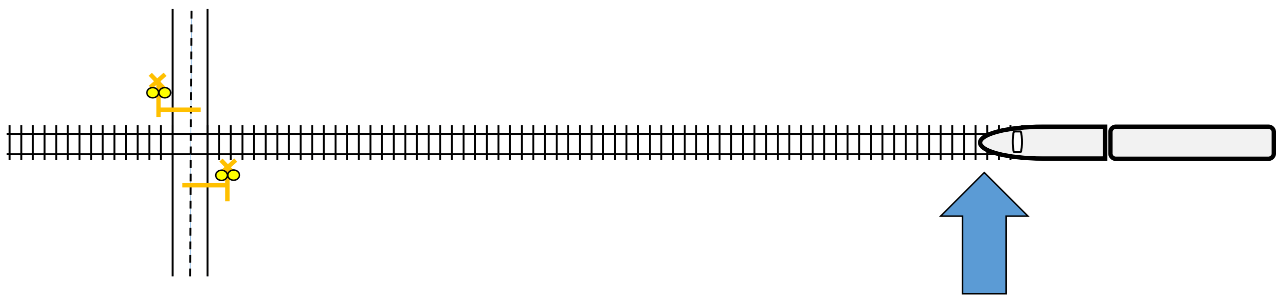
= 10 fatalities

And a similar increase in trespasser fatalities.

In 2014 there were approximately 480 trespasser fatalities at railroad tracks, an increase of 50 from the previous year.

Train Detection Technology – 1st Generation

- Physically linked to the railroad track circuitry
- Electrical current is run through an isolated block of tracks
- Presence of a train completes the circuit
- Circuit completion triggers safety devices at the crossing



Gate arms go down to ensure appropriate warning time based on the approaching train

Circuit based warning time device detects presence of a train

Train Detection Technology – 2nd Generation

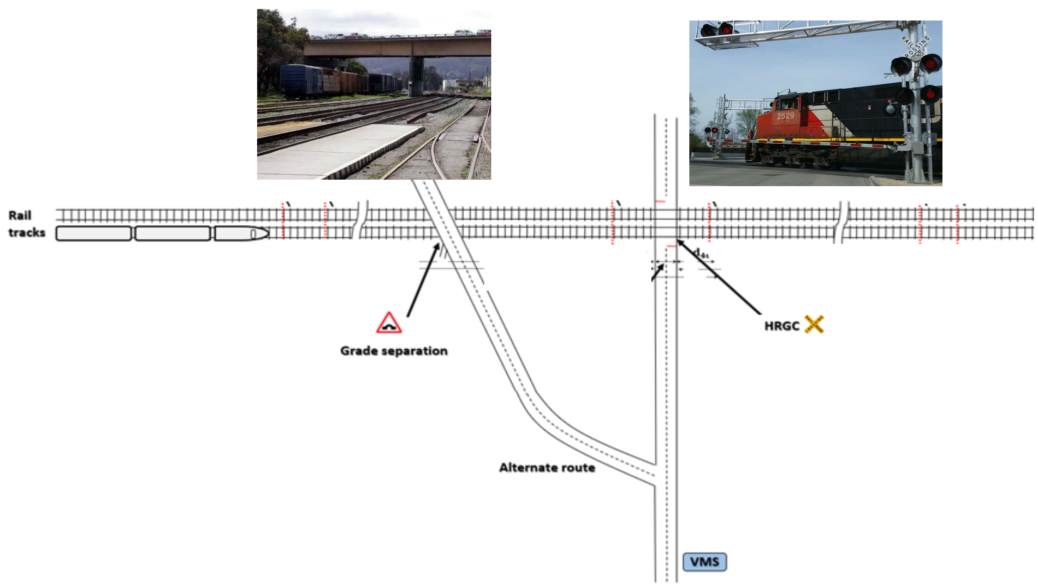
- More advanced detector equipment e.g., Radar, acoustic detection, vibration, laser detection, or video/optical detection
- Can provide a continuous stream of estimated train speed during the time that the train is detected
- More accurate prediction of a train's arrival at a crossing than 1st generation technologies
- May be deployed outside of railroad right-of-way
- But may not function well due to rain, multiple trains, snow blinding and sun glare

Train Detection Technology – 3rd Generation

- Provide continuously updated train information
- Can be integrated into the operation and management of railroad and motor vehicle network
- Commonly through the use of Global Positioning System (GPS) on trains
- Provides current position, speed, length, and other information on trains
- Requires instrumentation of GPS and other technologies on every train

An ITS Application to Highway-Rail Crossings

- Reduction of highway traffic at crossings when trains are nearby improves safety (reduced crash exposure)
- South Sioux City, NE requested an ATIS at a highway-rail Crossing



South Sioux City ITS Project – Train Detection

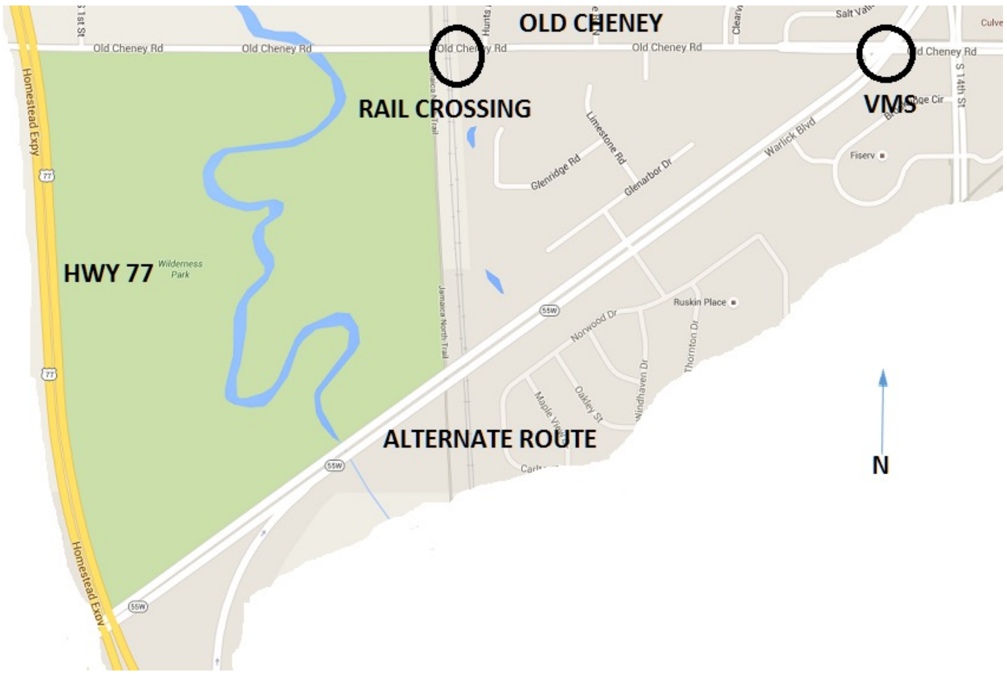
- Wheel sensors were used for train and train length detection in the system design
- Railroad company (BNSF) originally helped but then objected to the use of sensors due (liability considerations)
- Our point was that it will improve safety
- Project scrapped!
- Important lessons learned

Barriers to ITS Implementations At Crossings

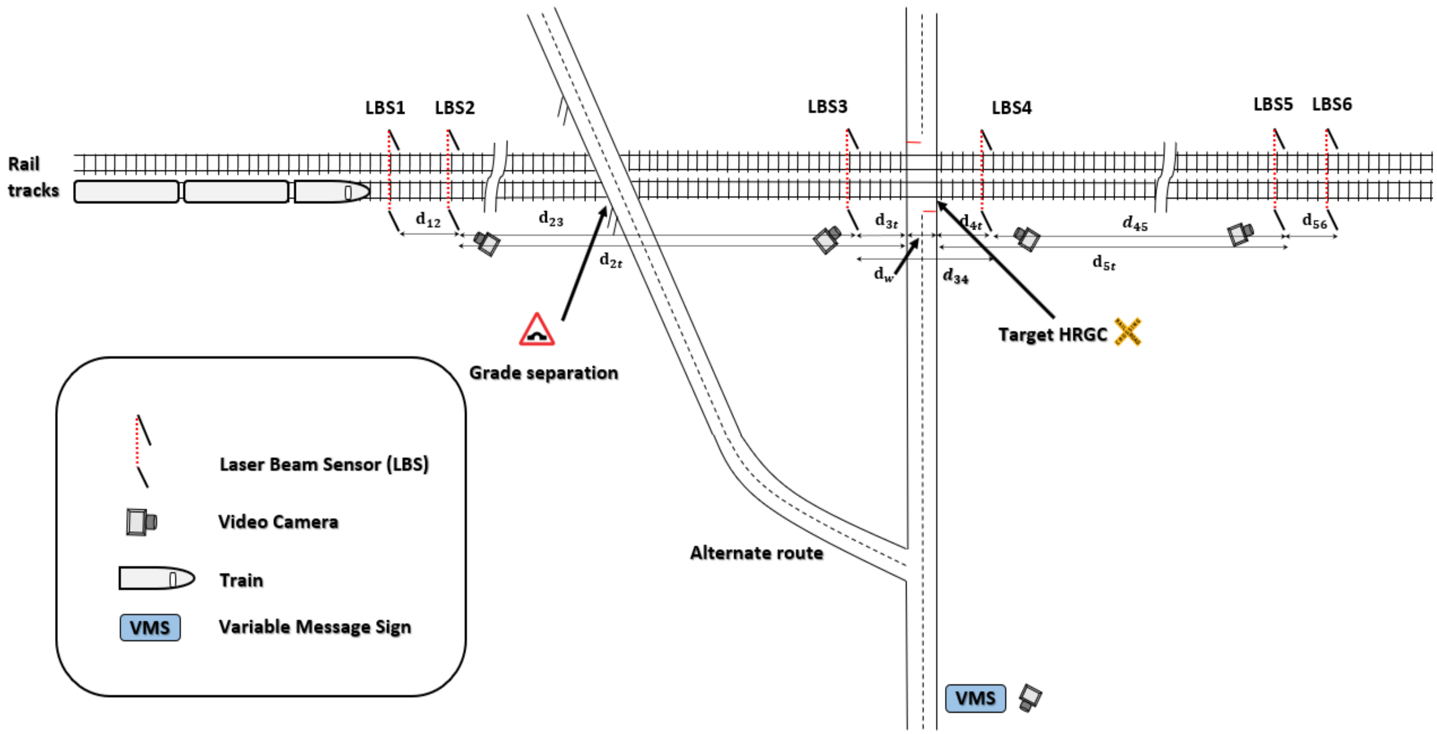
- Historic railway culture in the US
- Rail industry setup and business practices
- Railroads are private entities – most important element to them is profitability (cutting costs) and minimizing risk
- Protective of their right-of-way
- Litigation in case something bad happens because railroad companies have “deep pockets”
- Data availability (e.g., train schedules or location information) – railroads are protective and don’t wish to share

A More Recent ITS Application

- Highway-rail crossing located in Lincoln, NE
- Provide train occupancy information to motorists via Variable Message Sign (VMS)
- Motorist diversion to alternate route when information on train delay supplied?



System Setup



Train Occupancy Time Estimation System (TOTES)

- TOTES consists of three modules/subsystems:
  - Train detection subsystem (TDS)
  - Detection control subsystem (DCS)
  - Variable message sign (VMS) subsystem
- These three communicate with each other to obtain estimated train arrival at crossing and crossing occupancy time

Train Detection Subsystem

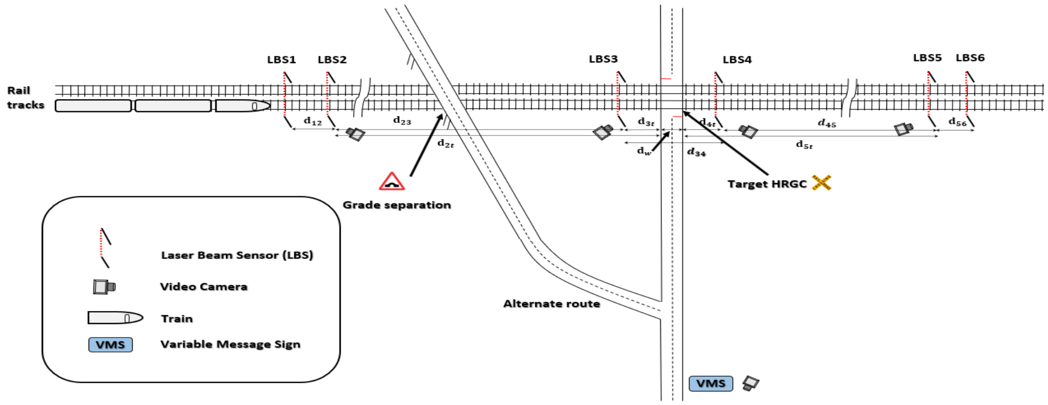


Table 3.1 Sample Time Log Information For a Train Crossing in TDS

Train Detection System (TDS): Train in a rightward direction							
LBS1		LBS2		LBS3		LBS4	
ON (t_{h1})	OFF (t_{t1})	ON (t_{h2})	OFF (t_{t2})	ON (t_{h3})	OFF (t_{t3})	ON (t_{h4})	OFF (t_{t4})
.	.	.	.	.	.	.	.
10:47:28	10:52:36	10:47:32	10:52:40	10:57:17	10:59:36	10:57:37	11:01:10
.	.	.	.	.	.	.	.

* t_{hi} = train head check-in time at LBS i
* t_{ti} = train tail check-in time at LBS i

Detection Control Subsystem

- Includes radio links to train detectors and a computer to link to detectors and communicate back and forth and wait for train's arrival.
- Upon train detection, the detectors forward data to the DCS, which processes the data, calculates train's arrival time and sends message to VMS via radio link

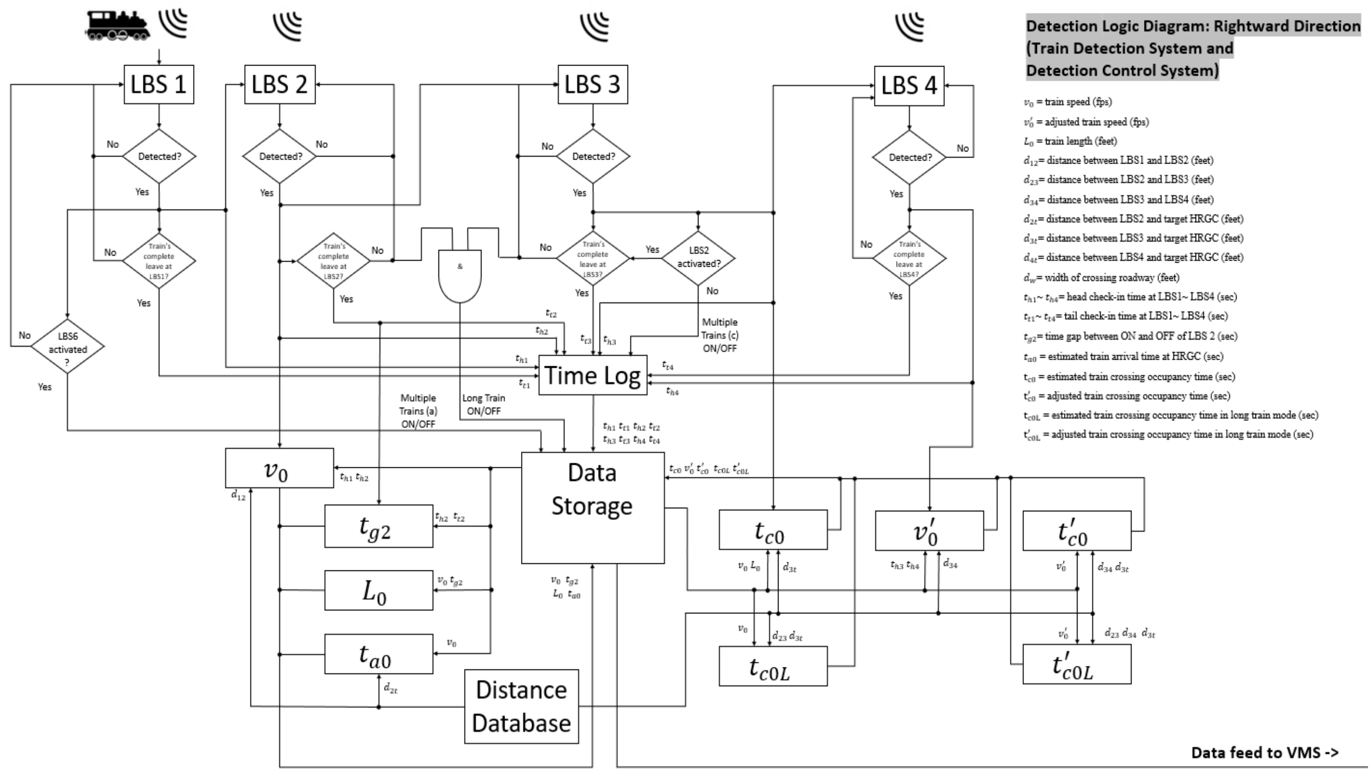
Table 3.2 Sample Data Information Processed by DCS

Detection Control System (DCS): Train in a rightward direction									
Time gap at LBS 2 (t_{g2})	Train speed (mph) (v_0)	Train length (Ft) (L_0)	Estimated arrival time at HRGC (min) (t_{a0})	Estimated crossing occupancy time (min) (t_{c0})	Adjusted train speed (v_0')	Adjusted estimated crossing occupancy time (min) (t_{c0}')	Long train mode	Estimated crossing occupancy time for long train (min) (t_{c0L})	Adjusted estimated crossing occupancy time for long train (min) (t_{c0L}')
.	.	.	.	.	.	.	.	.	.
4.0	46	5400	3	7	42	8	No	.	.
.	.	.	.	.	.	.	.	.	.

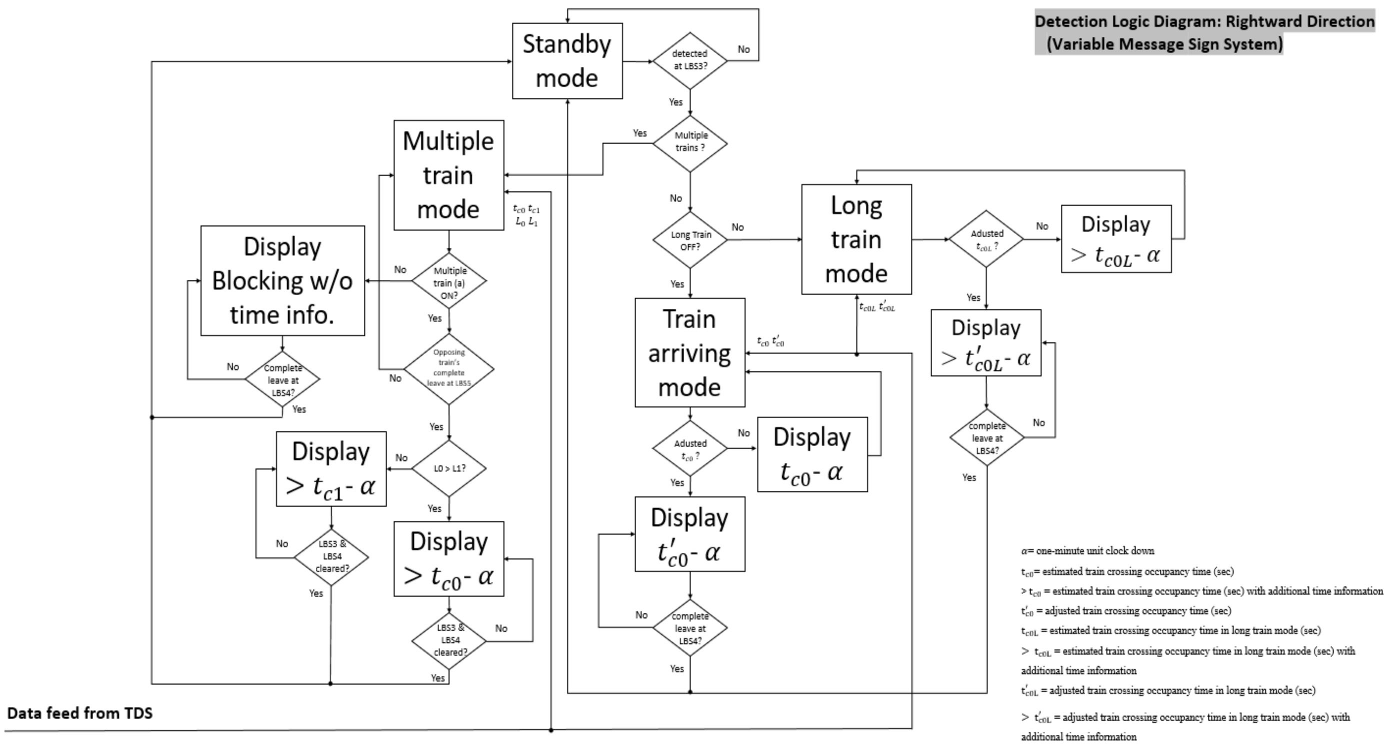
VMS Subsystem

- Standby mode
- Precaution mode
- Active mode

TOTES Logic (TDS and DCS)



TOTES Logic (VMS)



Some Issues with TOTES

- Simultaneous/overlapping train detection
- Cost of the whole system
- Manual input TOTES designed

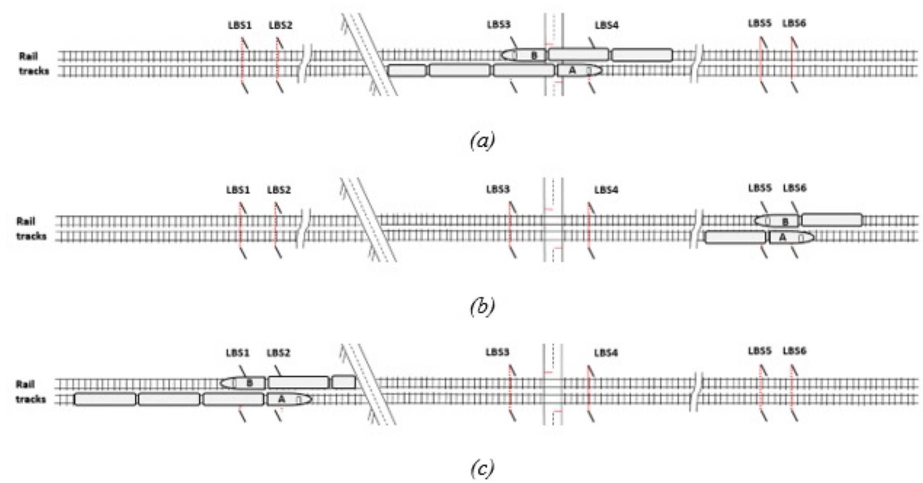


Figure 3.3 Scenarios of overlapped trains in multiple train mode

Data Collection

- Field setup

Figure 4.2 Configuration of data collection equipment for train activity data (left) and field-of-views from the installed IP camera (right above and below)

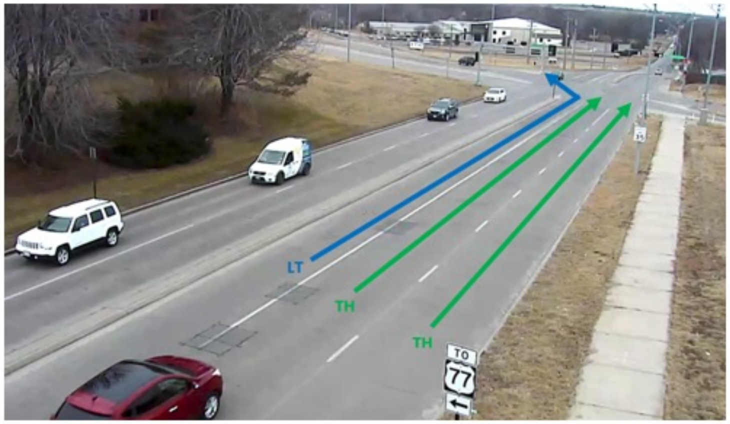


Figure 4.3 City of Lincoln traffic monitoring camera view

Diversion to Alternate Route

- Diversion to alternate route statistically significantly increased when the VMS train delay message was displayed with α = 10%

Table 5.4 Difference of VMS Effect on Rate of Left Turning Vehicles when Train Presents

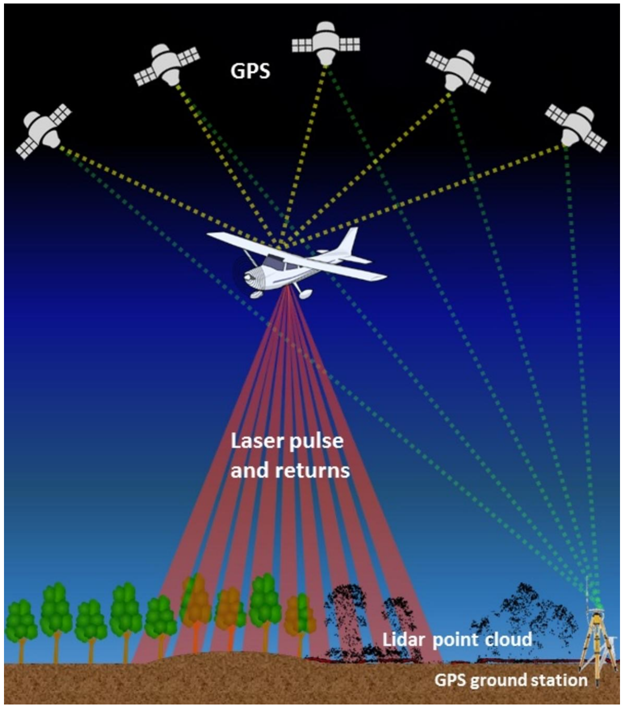
	VMS	N	Mean	SD	t	P-value
Rate of left turning vehicle	Not installed	120	0.404	0.175	1.738	0.084
	Installed	81	0.364	0.143		

- Issues with the VMS display and site geometry may have affected diversion rate
- Train delays were from 1.11 minutes to 6.52 minutes – longer delays will likely increase diversion
- Lesson learned: Keep projects costs in control

The issue of Vehicles with Long Wheelbase

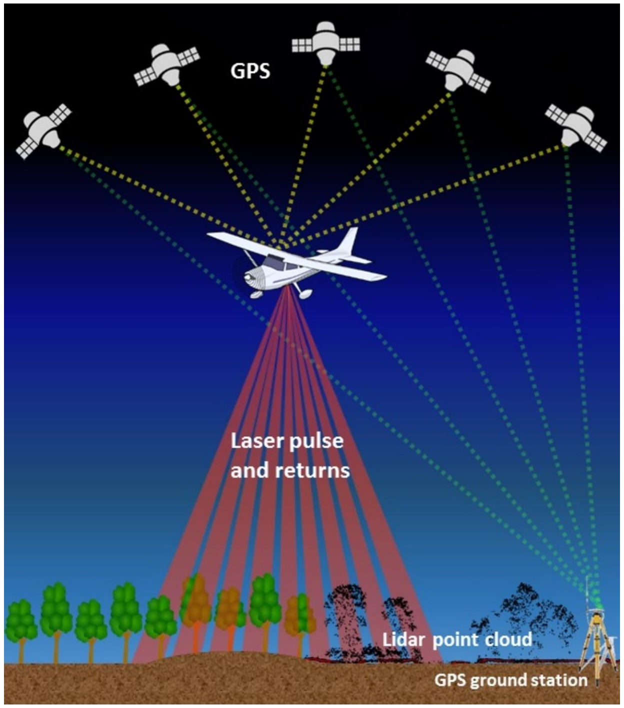
Application of LiDAR to Raised Crossings

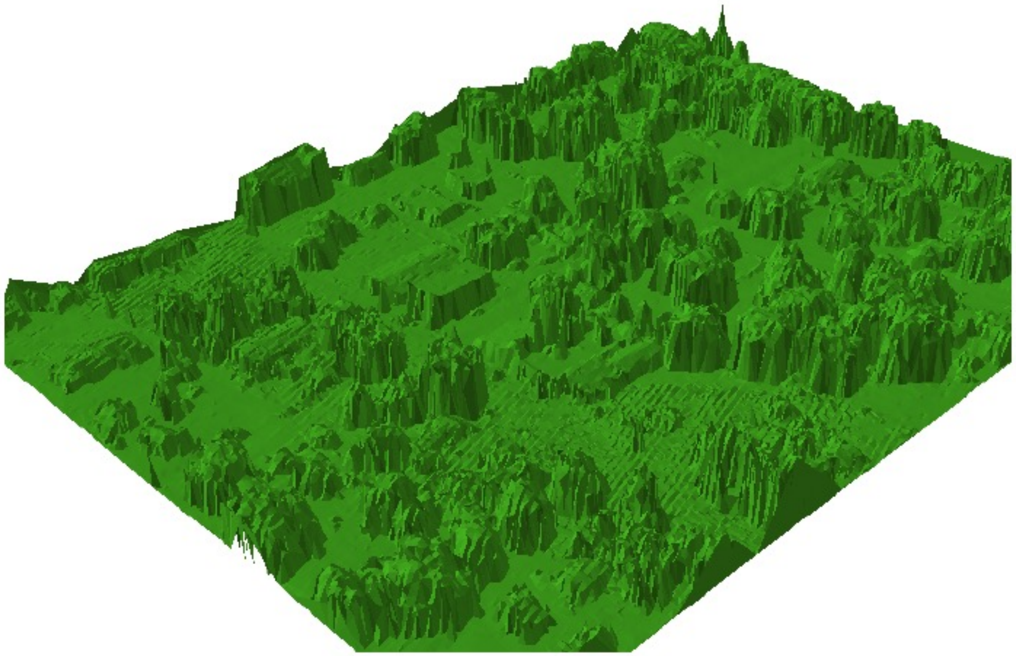
- LiDAR –Light Detection and Ranging



LiDAR –Light Detection and Ranging

- An airborne platform is essential for data collection
- 3-D Models can be made from collected data





Importance of Raised Crossing Assessment

- Traffic frequently diverted in emergencies (e.g., flooding)
- A vehicle that gets stuck on train tracks will create further issues for both modes of transport
- Many agencies in the US collecting LiDAR data
- 3-D topographic models can be made from available LiDAR data using GIS
- Raised crossings may be assessed in GIS but how accurate is this method?

Study Locations in Lincoln, Nebraska

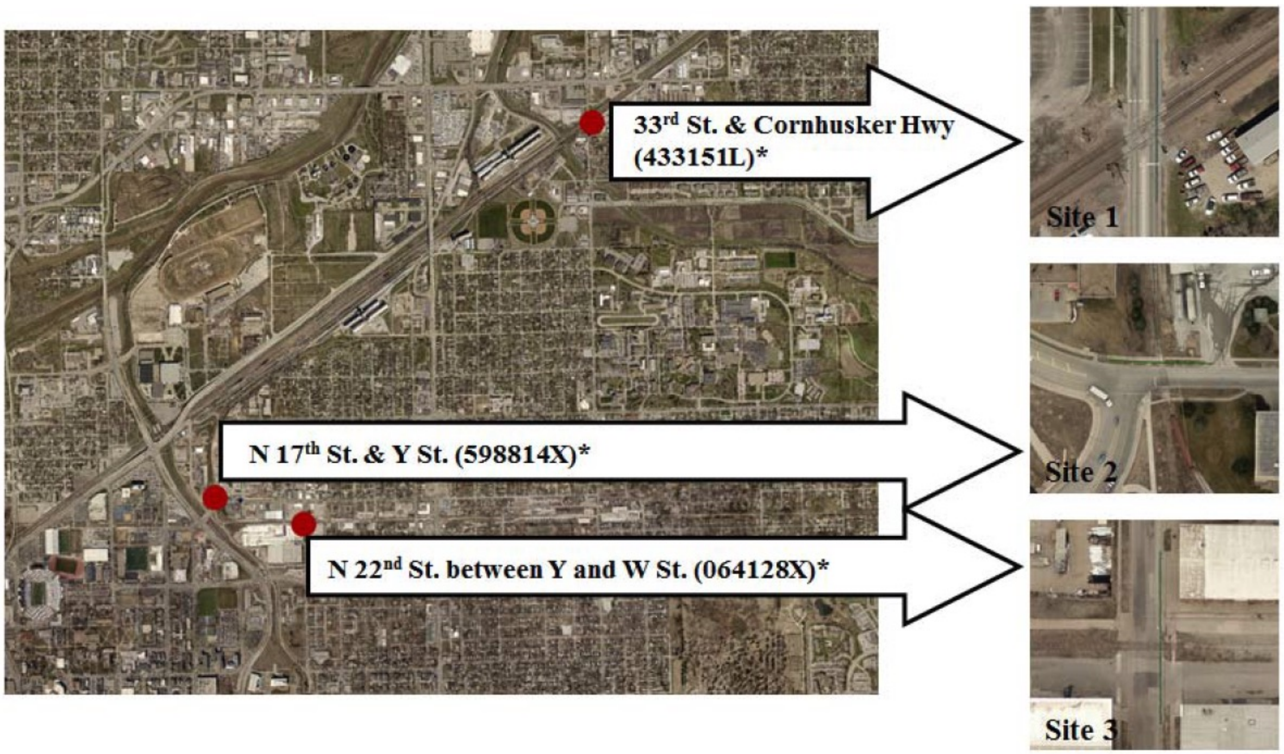


Figure 3 Selected highway-rail crossings in Lincoln, Nebraska
(* US DOT crossing number)

Research Methodology

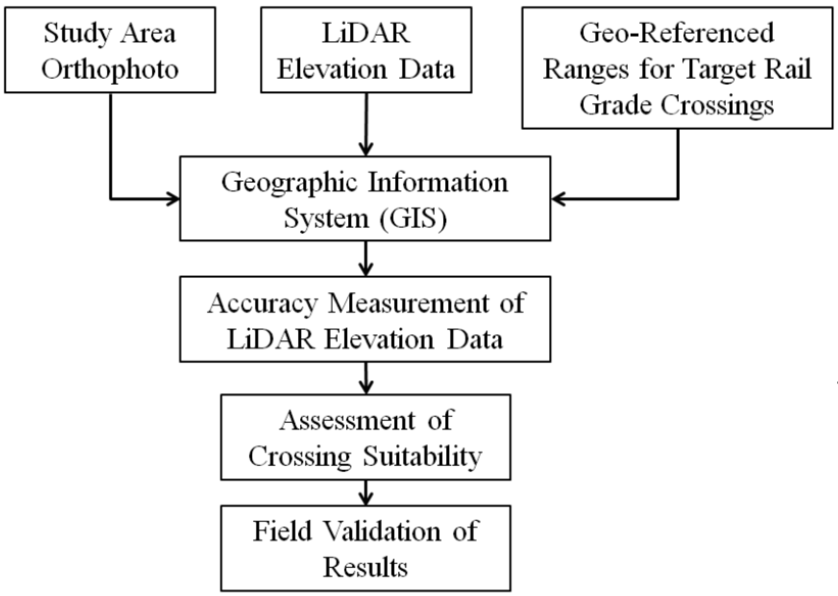


Figure 2 Research methodology

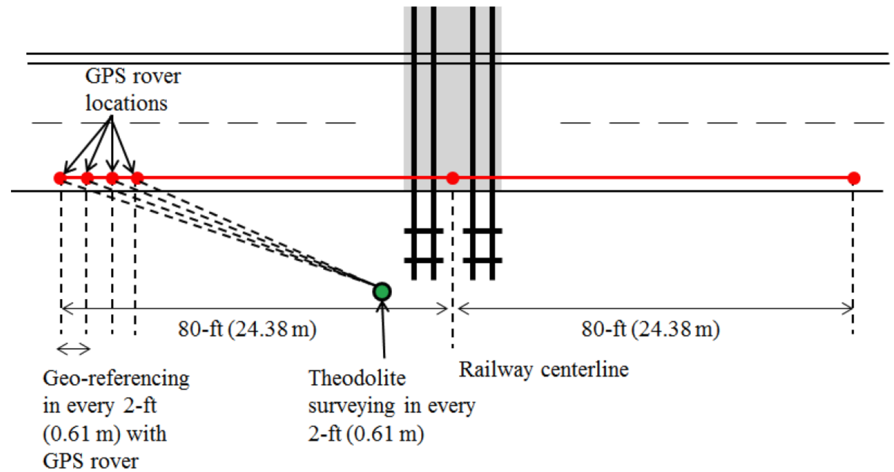


Figure 4 Geo-referencing at a highway-rail crossing

Comparison - LiDAR vs Field-Collected Data

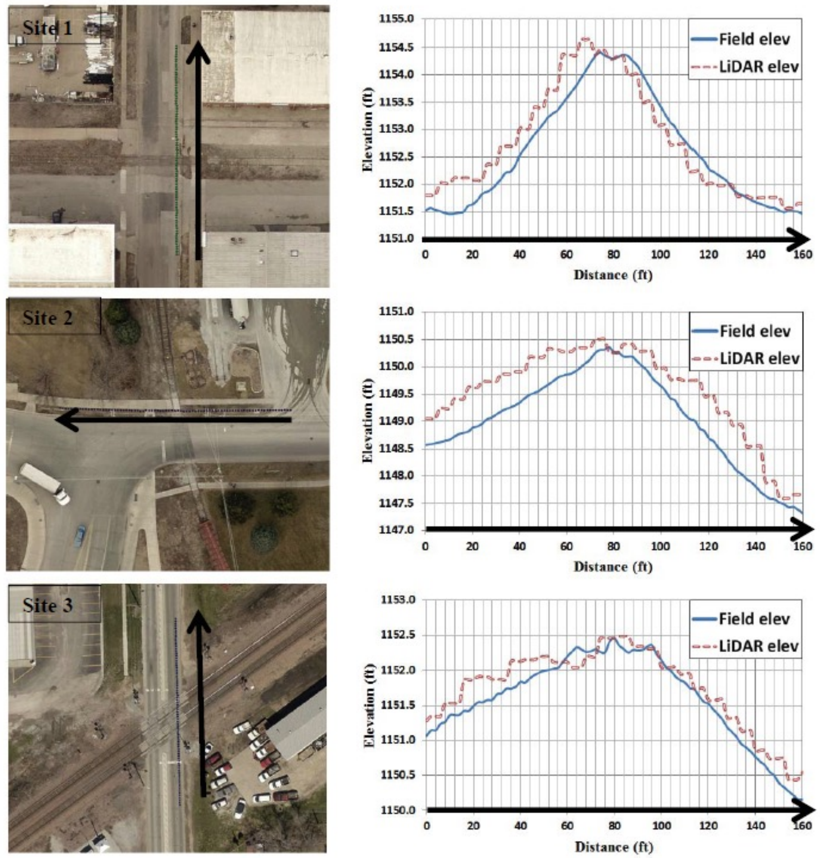


Figure 5 Comparison of vertical elevation profiles for LiDAR and field-measured data

Design Vehicles

Table 1 Selected Design Vehicle Dimensions [Source: French et al. (2002)]

Design Vehicle	Wheelbase (ft)	Front Overhang (ft)	Rear Overhang (ft)	Ground Clearance (in)		
				Wheelbase	Front Overhang	Rear Overhang
Rear-Load Garbage Truck	20	-	10.5	12	-	14
Aerial Fire Truck	20	7	12	9	11	10
Pumper Fire Truck	22	8	10	7	8	10
School Bus	23	-	13	7	-	11
Lowboy Trailers <53 feet	38	-	-	5	-	-
Car Carrier Trailer	40	-	14	4	-	6

Notes: - indicates no hang-up problems due to this part of the vehicle

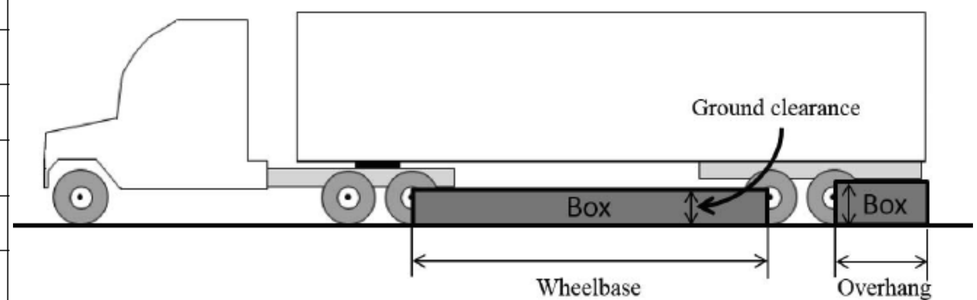


Figure 6 Semi trailer with imaginary box under the trailer

GIS Analysis

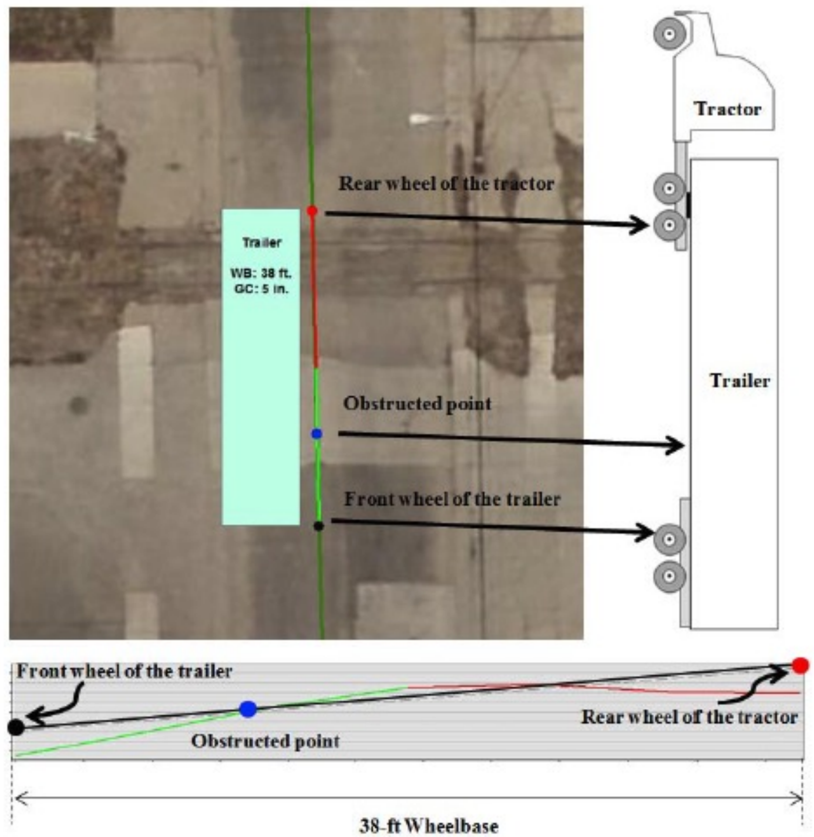


Figure 7 Identification of crossing suitability of a trailer with 38-ft (11.58 m) wheelbase and 5 inches (0.127 m) ground clearance at site 1

Field Validation

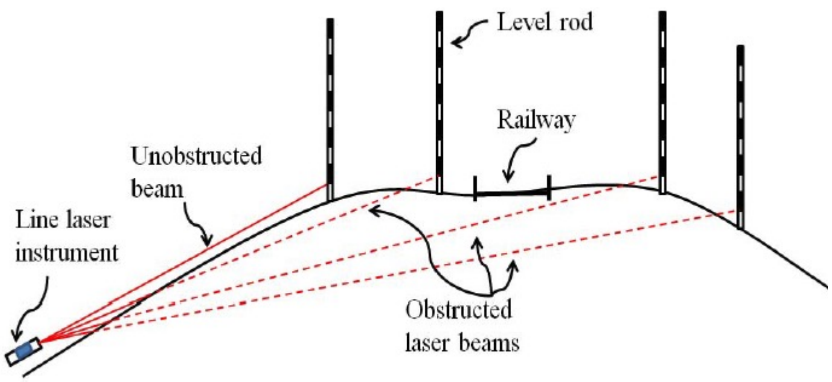


Figure 8 Illustration of the field validation of GIS-derived results

Table 2 Result of Crossing Suitability of Selected Design Vehicles

Design vehicles	Site 1			Site 2			Site 3		
	Wheel-base	Front overhang	Rear overhang	Wheel-base	Front overhang	Rear overhang	Wheel-base	Front overhang	Rear overhang
Rear-Load Garbage Truck	No hang-up	NA	No hang-up	No hang-up	NA	No hang-up	No hang-up	NA	No hang-up
Aerial Fire Truck	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up
Pumper Fire Truck	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up	No hang-up
School Bus	No hang-up	NA	No hang-up	No hang-up	NA	No hang-up	No hang-up	NA	No hang-up
Lowboy Trailers <53 feet	Hang-up	NA	NA	No hang-up	NA	NA	No hang-up	NA	NA
Car Carrier Trailer	Hang-up	NA	No hang-up	Hang-up	NA	No hang-up	No hang-up	NA	No hang-up

NA: Not applicable

Conclusions

- Validation of the GIS derived results in the field showed that all the identified blockage spots were correctly identified
- LiDAR data can be successfully used to analyze raised highway-rail crossings for the passage of different vehicles
- This method is efficient and safer because it avoids making measurements in the field where highway and train traffic may pose hazards
- LiDAR data updates are infrequent and changes to rail or highway network will void GIS analysis

Some Videos

Questions?